2-p(m1X) NTIS HC $3.75

X-325-72-376
PREPRINT

NASA TM X- 66125

UK-4 FLIGHT SPACECRAFT MAGNETIC TESTS

W. E. PRUETT

(NASA-TM-X-66125) UK-4 FLIGHT SPACECRAFT MAGNETIC TESTS W.E. Pruett (NASA) Apr. 1972 31 p CSCL 22B
N73-13912
Unclas
G3/31 50359

APRIL 1972

GSFC GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

29

X-325-72-376

UK-4 FLIGHT SPACECRAFT

MAGNETIC TESTS

W. E. Pruett

Test and Evaluation Division
Systems Reliability Directorate

April 1972

GODDARD SPACE FLIGHT CENTER
Greenbelt, Maryland

PRECEDING PAGE BLANK NOT FILMED

UK-4 FLIGHT SPACECRAFT MAGNETIC TESTS

Test Engineers: W. D. Kenney, J. C. Boyle, C. A. Harris, T. N. Roy

Prepared by: W. E. Pruett

W. E. Pruett

Reviewed by: C. Leland Parsons

C. Leland Parsons
Head, Magnetic Test Section

Approved by: William G. Brown

William G. Brown
Head, Functional Test Branch

Approved by: Fred Starbuck

Fred Starbuck
Associate Chief, Test and Evaluation Division

Preceding page blank

PROJECT STATUS

This is the final report on magnetic testing of the UK-4 Flight Spacecraft. The spacecraft was successfully launched by a NASA Scout Rocket on December 11, 1971, into a 500 kilometer circular orbit.

AUTHORIZATION

Test and Evaluation Charge No. 325-870-41-25-02

[redacted]

UK-4 FLIGHT SPACECRAFT MAGNETIC TESTS

W. E. Pruett
Test and Evaluation Division

SUMMARY

The UK-4 flight spacecraft was tested in GSFC Spacecraft Magnetic Test Facility. The tests were conducted during the period October 12 through October 14, 1971.

The results of measurements made during the tests are tabulated below.

Dipole Moments in Milliampere Meters Squared (Pole-Cm)			
Spacecraft Status	Z	XY	Total
Initial Perm	1000 Dn	2140	2362
Post 1.5 Millitesla (15 Gauss) Vertical Exposure	2850 Dn	2180	3588
Post 2.5 Millitesla (25 Gauss) Vertical Deperm	690 Dn	2020	2135
Post 2.5 Millitesla (25 Gauss) Horizontal Deperm	515 Dn	1050	1169
Post 2.5 Millitesla (25 Gauss) Rotation Deperm	400 Dn	1000	1077
Post Magnet Compensation	85 Up	1000	1004
Induced:			
30 Microtesla (30 K Gamma) North		1193 N	
30 Microtesla (30 K Gamma) East		1400 E	
30 Microtesla (30 K Gamma) Down	1128 Dn		
Post Induced	85 Up	1050	1053
Stray		(Negligible)	
Post Stray	85 Up	1030	1034

Eddy Current and Hysteresis Torques were as follows:

Field			Torque in Newton Meters x 10^{-7} (Dyne-cm)
Magnitude	Dir	Frequency	
30 Microtesla	CW	10.5 Rad/Sec	114 CW
30 Microtesla	CW	3.15 Rad/Sec	38 CW

Torque Coil Moment = 49,000 ±5000 Milliampere-Meters Squared at 14.8 volts.

PRECEDING PAGE BLANK NOT FILMED

CONTENTS

Preceding page blank

ILLUSTRATIONS

TABLES

UK-4 FLIGHT SPACECRAFT MAGNETIC TESTS

INTRODUCTION

The UK-4 spacecraft is a cooperative United Kingdom/United States satellite to investigate plasma-charged streams and electromagnetic waves in the upper atmosphere. The fourth satellite in the series was successfully launched into a 500 kilometer circular orbit by a NASA Scout rocket on December 11, 1971 from the Western Test Range, California. Called Ariel 4, the 99.8 kilogram (220 pound) satellite carries one U.S. and four British experiments to study the ionosphere.

A magnetic torquing system will be used for attitude control of the UK-4 spacecraft. It was used for initial orientation of the spacecraft spin axis after insertion into orbit and will be used for subsequent maintenance of the desired attitude to within a cone of 5 degrees semi-angle about Earth's polar axis. The coil axis is parallel to the spin axis to provide maximum useful torque when the local field vector is normal to the spin axis. The coil is operated on command from the ground. The design goal for the spin axis moment is a nominal value of 90,000 milliampere-meters squared (mA-m^2) at 16.0 volts.

OBJECTIVES

Objectives of the magnetic tests were:

- To determine the permanent, induced and stray magnetic moments of the spacecraft and to assess its magnetic stability.
- To determine the dipole moment produced by energizing the magnetorquer coil.
- To measure the despin torque due to eddy current and magnetic hysteresis.
- To deperm, compensate, and make other adjustments necessary to achieve satisfactory magnetic characteristics for the spacecraft.

TEST DESCRIPTION

Setup — The UK-4 spacecraft was tested in the GSFC Spacecraft Magnetic Test Facility, which uses a 12.8 meter (42 foot) diameter Braunbek coil system to produce a controlled magnetic field of high uniformity over a large central volume. Appendix A describes the facility.

The UK-4 spacecraft was mounted on the Mark VI torquemeter through the ten degree tilt plate designed for the S^3 tests. The torquemeter, shown in Figure 1, was immobilized during the acquisition of magnetic data and was activated for the torque measuring portion of the test. This assemblage was mounted on the turntable dolly with an intermediate spacer to bring the center of the main body of the spacecraft in line with the array of magnetometers and was positioned at the center of the 12.8 meter (42 foot) coil system with the +X axis of the spacecraft oriented to the north, its +Y axis directed east, and its +Z axis directed upwards. The set-up is shown in Figure 2.

Magnetic measurements were made at locations 1.829 meters (6 feet), 2.438 meters (8 feet), 3.048 meters (10 feet) and 3.658 meters (12 feet) north of the coil system center at an elevation of 1.505 meters (59.25 inches) above the floor level (probe locations are depicted in Figure 3). The signals from the probes were hard wired to the Operations and Instrumentation Building for monitoring. The signals were displayed as meter indications and as analog tracers on brush recorders. They were also recorded in digital coding on a magnetic tape (MADAS). The meter reading and analog traces were used for real time "quick look" monitoring. The MADAS data were processed by digital computer programmed to perform a near field analysis of dipole moment.

In order to make torque measurements it was only necessary to activate the torquemeter while using the same assemblage as in the magnetic tests. With the spacecraft at the center of the coil system, the floor rugs and plastic curtain were installed to minimize spurious torques produced by stray air currents. When the spacecraft was tilted a counter-balance was used, consisting of a 12.25 kilogram (27 pound) mass at 45.7 cm (18 inches) lever arm. The instrumentation consisted of the basic torquemeter electronics, electronic filter and two 2-channel Sanborn recorders with synchronized time marks. A block diagram is shown in Figure 4.

Procedure — Magnetic tests consisted of the following:

- Measurement of initial permanent dipole moment.
- 1.5 millitesla (15 gauss) exposure and subsequent dipole moment measurement.
- Deperm from 2.5 millitesla (25 gauss) maximum and subsequent dipole moment measurement.

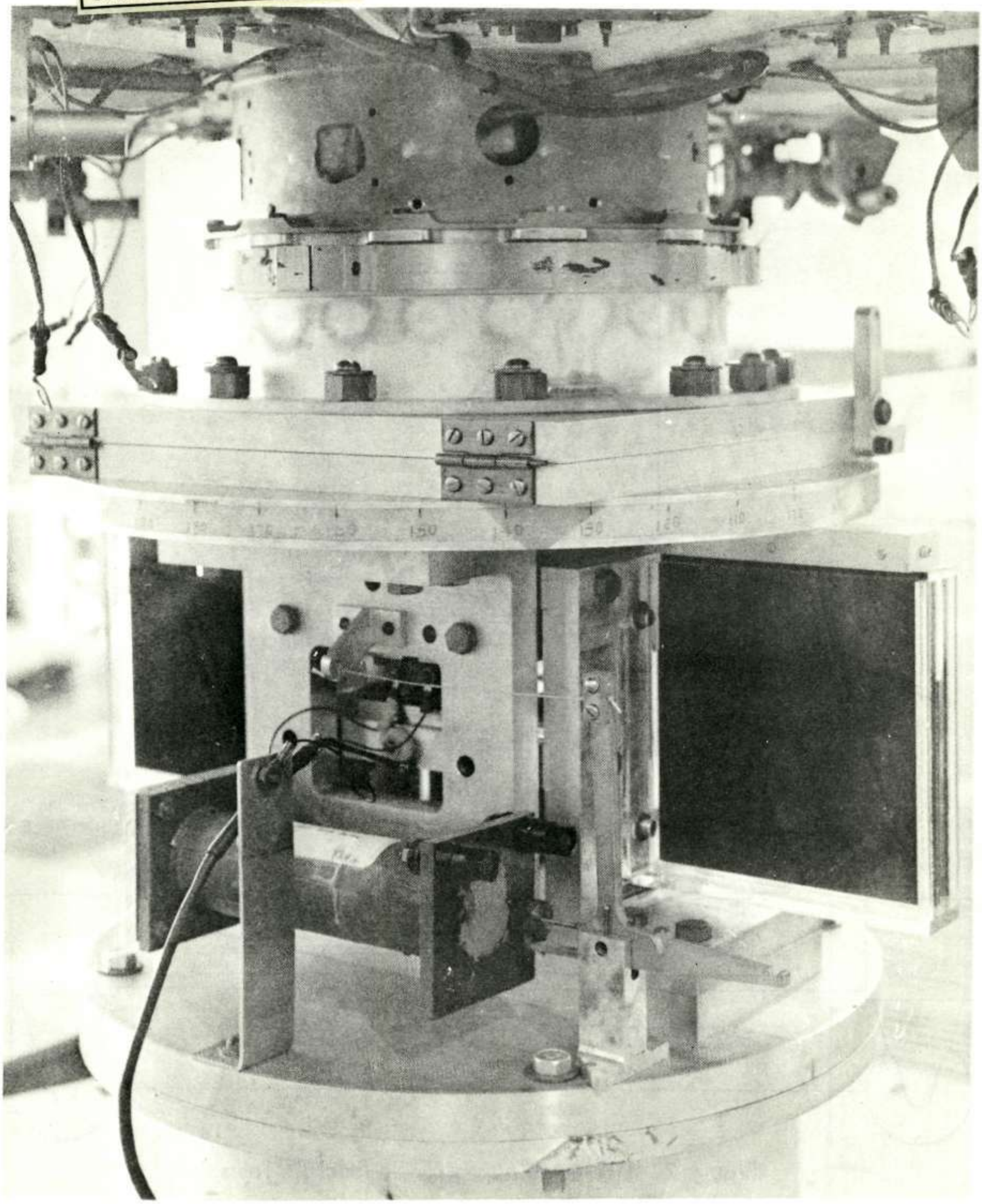


Figure 1. Mark VI Torquemeter

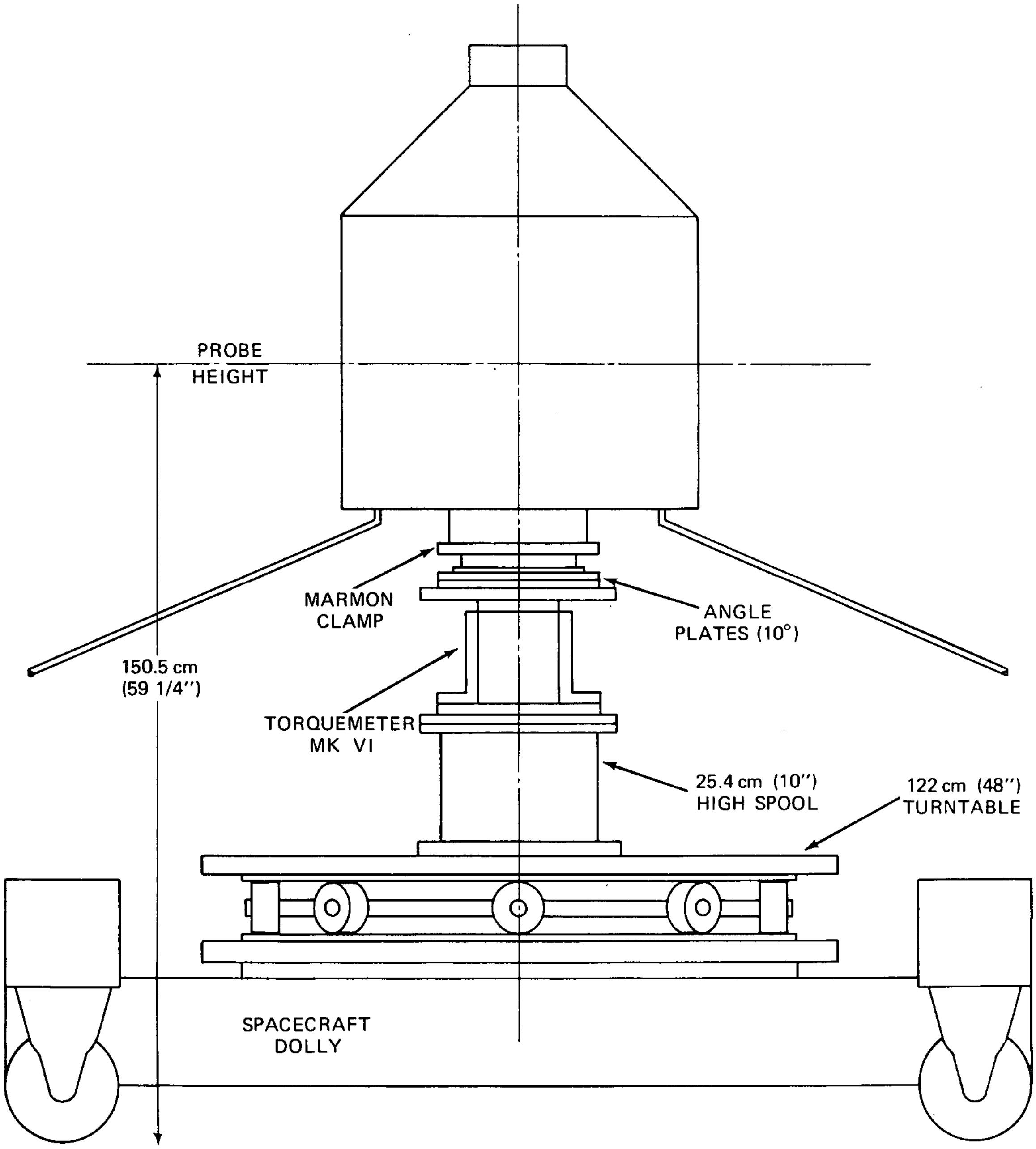


Figure 2. UK-4 Mounting for Spacecraft Tests

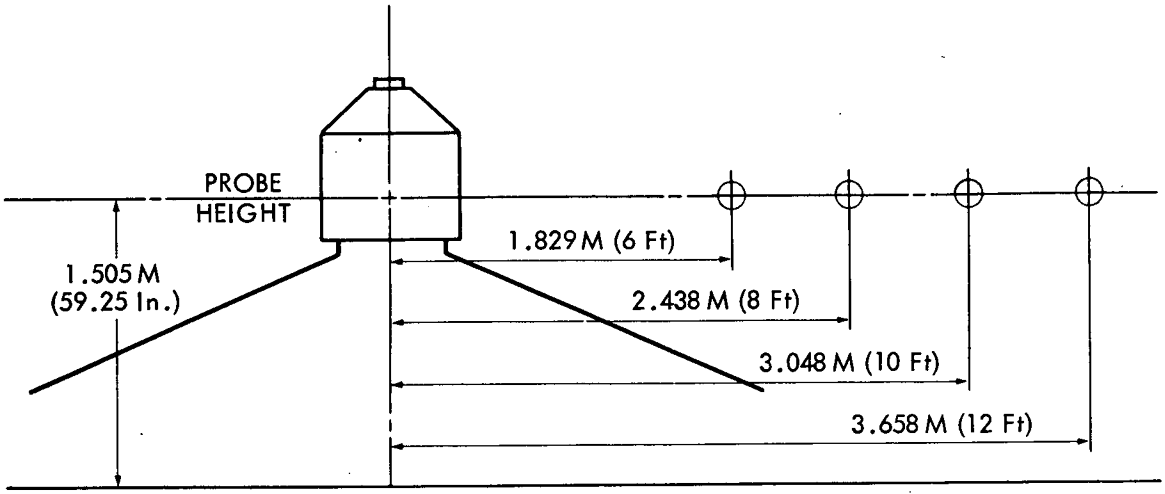


Figure 3. Probe Locations for UK-4 Spacecraft Test

- Vertical compensation and subsequent dipole moment measurement.
- Measurement of induced dipole moments.
- Measurement of stray fields dipole moments.
- Measurement of torquer coil moment and torque.
- Eddy current and hysteresis torque.

Appendix B contains details of the procedures followed in performing these tests, as well as the computational techniques used.

TEST RESULTS

Magnetic Moment — The magnetic moment record for the spacecraft appears in Table I. Although the post deperm magnetic moment was less than the moment in the initial state, the vertical component was greater than the 1000 mA-m^2 nominal called for in Reference 2. It was therefore necessary to introduce compensation in order to reduce the vertical component to its final value of 85 mA-m^2.

The change in moment due to drawing current from the solar cells while stimulated by a bank of sun guns was negligible.

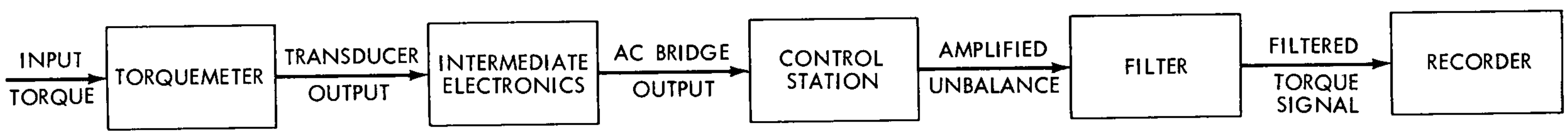


Figure 4. Block Diagram of Torque Measuring System

Table I

Magnetic Moments

Dipole Moments in Milliampere Meters Squared (Pole-cm)			
Spacecraft Status	Z	XY	Total
Initial Perm	1000 Dn	2140	2362
Post 1.5 Millitesla (15 Gauss) Vertical	2850 Dn	2180	3588
Post 2.5 Millitesla (25 Gauss) Vertical Deperm	690 Dn	2020	2135
Post 2.5 Millitesla (25 Gauss) Horizontal Deperm	515 Dn	1050	1169
Post 2.5 Millitesla (25 Gauss) Rotational Deperm	400 Dn	1000	1077
Post Magnet Compensation	85 Up	1000	1004
Induced:			
30 Microtesla (30K Gamma) North		1193 N	
30 Microtesla (30K Gamma) East		1400 E	
30 Microtesla (30 Gamma) Down	1128 Dn		
Post Induced	85 Up	1050	1053
Stray		(Negligible)	
Post Stray	85 Up	1030	1034

The permanent moment measurements taken before and after exercising the magnetorquer coil are in agreement, indicating that the use of the coil does not cause any significant change in spacecraft perm.

The change in moment due to energizing the various experiments was negligible.

Torque Measurement — The results of the torquemeter dipole measurements are shown in Table II. The average value of Z axis moment of the torquer coil was 53,634 mA-m^2 (pole-cm) at 14.8 volts, or 59,802 mA-m^2 at 16.5 volts. This is down from the value of 66,213 mA-m^2 at 16.5 volts measured on the prototype.

Table II

UK-4 Torquemeter Test Results

Item	Dipole Moment in Milliampere-Meters Squared (Pole-cm)			
	M_x	M_y	M_z	M_t
Pre-Magnetorquer Perm	35 N	1028 E	80 Up	1,032
Magnetorquer Coil Moment - Forward	129 S	999 W	52,000 Dn (14.8 Volts)	52,010
Magnetorquer Coil Moment - Reversed	171 N	1028 E	52,268 Up (14.8 Volts)	55,278
Post Magnetorquer Perm	12 N	1028 E	80 Up	1,031

Field in Nanoteslas (Gammas)			Eddy Current and Hysteresis Torque in Newton Meters x 10^{-7} (Dyne cm)
Magn.	Dir	Frequency	
30,000	CW	10.5 r/s	114
30,000	CW	3.5 r/s	38

CONCLUSIONS

All magnetic tests which were performed on both the prototype and the flight spacecraft produced comparable results which were within established guidelines. There was one apparent discrepancy observed in the magnetorquer coil moments between prototype and flight units, however, further investigation indicated that this was due to a difference in configuration of the two coils which resulted in a difference in effective areas. Testing performed in the field at WTR confirmed this hypothesis. Results of the WTR field tests are contained in Appendix C.

In addition to the magnetic tests which were repeated on the flight unit, there were certain tests performed on the prototype unit which were not repeated on the flight unit, for obvious reasons. The results of these tests are included here in the flight report in order to complete the picture. The tests and results are as follows:

- Magnetic field measurements taken in the vicinity of the folded booms indicate the maximum field due to the magnetorquer coil to be no more than 50 microtesla (0.5 gauss). When combined with the field due to the permanent magnetization, a maximum of 90 microteslas (0.9 gauss) was present. Since normal earth's field is 70 microtesla (0.7 gauss), the additional exposure is negligible.

- When the facility field was rotated with the magnetorquer coil energized, a sinusoidal torque was produced at the frequency of rotation. Furthermore, the phase of this torque with respect to the rotating field was the same as when the torquemeter solenoid was energized (actually 180° out of phase). This leads to the conclusion that the observed torque is entirely consistent with a coil moment which is constant in magnitude and direction. It thus appears that no spurious torques are produced due to mechanical oscillation, if any, of the unsupported elements of the coil.

PROBLEMS

The Iowa experiment was not available at the time of the testing of the flight model. The experiment is to be separately depermed before re-integration into the flight spacecraft.

ACKNOWLEDGEMENT

The magnetic testing of this spacecraft and the acquisition of all data presented were accomplished as a team effort by the personnel of the Magnetic Test Section, GSFC. Acknowledgement is also made of the excellent cooperation of the personnel of British Aircraft Corporation, Ltd., the UK-4 project personnel and by D. M. Shipley, the T&E flight project support manager.

REFERENCES

1. Design Review on Magnetic Torquing System, prepared by British Aircraft Corporation, Ltd., dated 3 April 1971.

2. Magnetic Moment Tests on the Flight UK-4 Spacecraft, prepared by British Aircraft Corporation, Ltd., dated 20 April 1971.

3. GSFC Report X-325-69-350 by W. L. Eichhorn, dated August 1969, entitled "New Method for Determination of the Magnetic Dipole Moment of a Spacecraft from Near Field Data."

4. NASA TN D-6387, by J. C. Boyle, entitled "The Mark VI Torquemeter, An Instrument for Measuring Magnetic Torques on Spacecraft," dated August 1971.

APPENDIX A

DESCRIPTION OF MAGNETIC TEST FACILITY

The Spacecraft Magnetic Test Facility at Goddard Space Flight Center produces a controlled magnetic environment for magnetic tests of spacecraft or spacecraft components. The 12.8 meter (42 foot) diameter three-axis coil system permits establishment of zero field, or of a field of any desired magnetude and direction with a maximum of 60,000 nanoteslas (gammas) per component. Current-regulated power supplies provide stability of ±1 nanotesla (gamma) over a 24-hour period, and the coil geometry provides uniformity of field within 0.6 nanotesla (gamma) over a spherical volume of 2-meters (6.6 feet) diameter. Three earth-field magnetometers and associated control systems provide automatic compensation for the daily variation of the earth's field. Figure A-1 illustrates the total magnetic field reconnaisance survey of the magnetic test site.

Besides generating static magnetic fields, the coil currents are programmable to produce a resultant vector that will rotate about any desired axis through the center of the coil system at a maximum rate of 100 radians per second. The magnitude of the rotating vector has a maximum limit of 60,000 nanoteslas (gammas).

The facility also includes a 2,268 kilogram (5,000 pound) capacity overhead hoist, a 907 kilogram (2,000 pound) capacity hydroset for gentle handling of delicate spacecraft, a track system and dolly for transporting the spacecraft from the truck lock to the center of the coil system, and a turntable at the coil center powered to rotate the spacecraft through 360 degrees while it is centered in the coil.

An angle encoder on the turntable permits synchronization of angular position and magnetic measurements. A gimbal is available that can rotate the spacecraft about a horizontal axis.

A portable 2.7 meter (9 foot) diameter Helmholtz coil generates fields up to 2.5 millitesla (25 gauss) for perming and deperming the spacecraft along one axis. Also available is a 1.5 meter (5 foot) diameter coil for applying such fields along a second axis of the smaller spacecraft.

A series of highly sensitive torquemeters are available, permitting direct measurement of torques resulting from the interaction between the magnetic moment of the spacecraft under test and the field produced by the coil system itself. The torquemeter used in testing the UK-4 spacecraft is designated as Mark VI and is described in Reference 4.

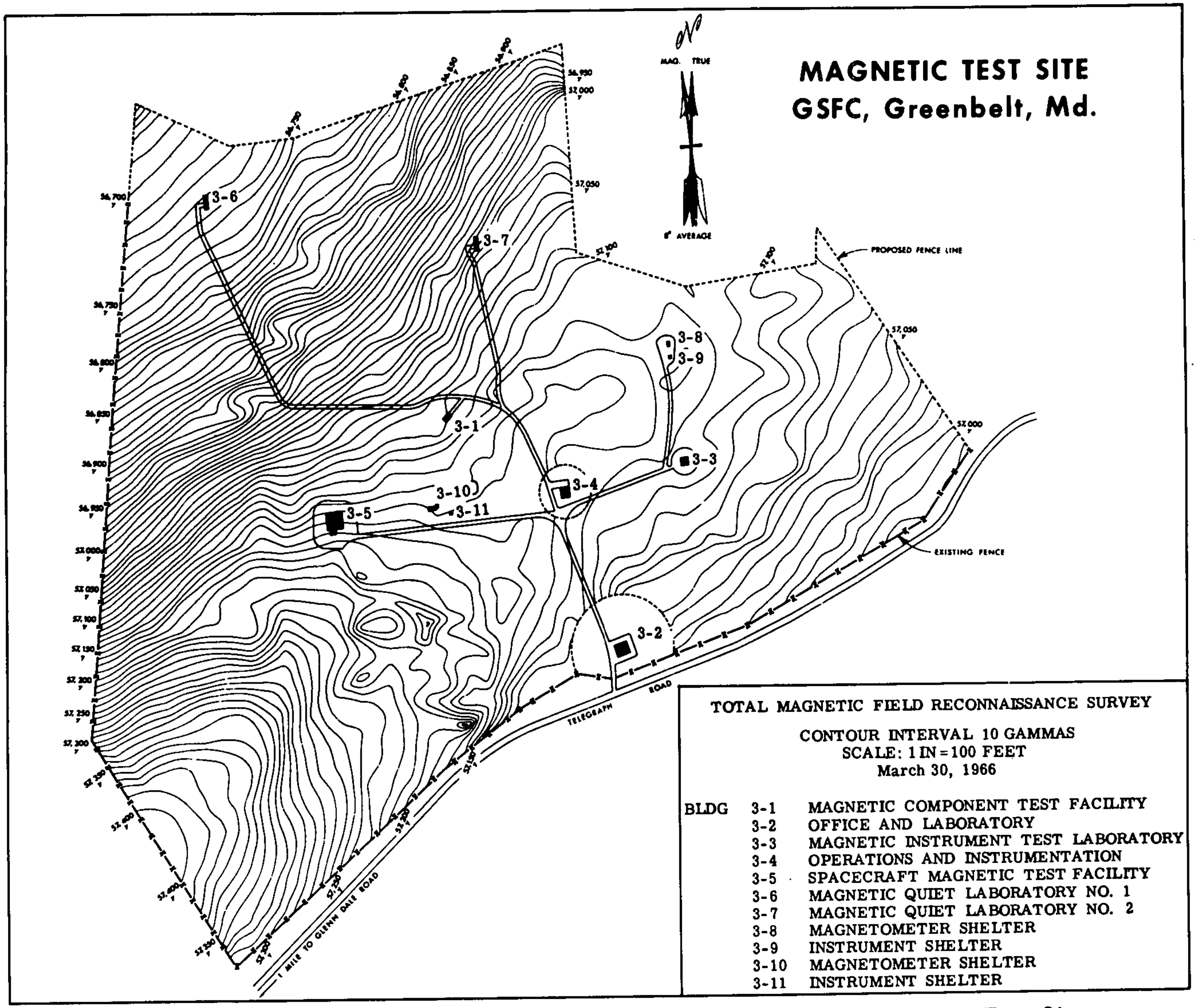


Figure A-1. Total Magnetic Field Reconnaisance Survey of Magnetic Test Site

The equipment also includes four triaxial fluxgate magnetometers that can be used simultaneously to provide meter display, strip chart records, and digital printout records. The positions of the magnetometer probes can be varied to suit the particular needs of the spacecraft or subsystem under test.

Figure A-2 is a photograph of the recording instrumentation for the magnetic tests, and Figure A-3 is a photograph of the UK-4 spacecraft in the Magnetic Test Facility.

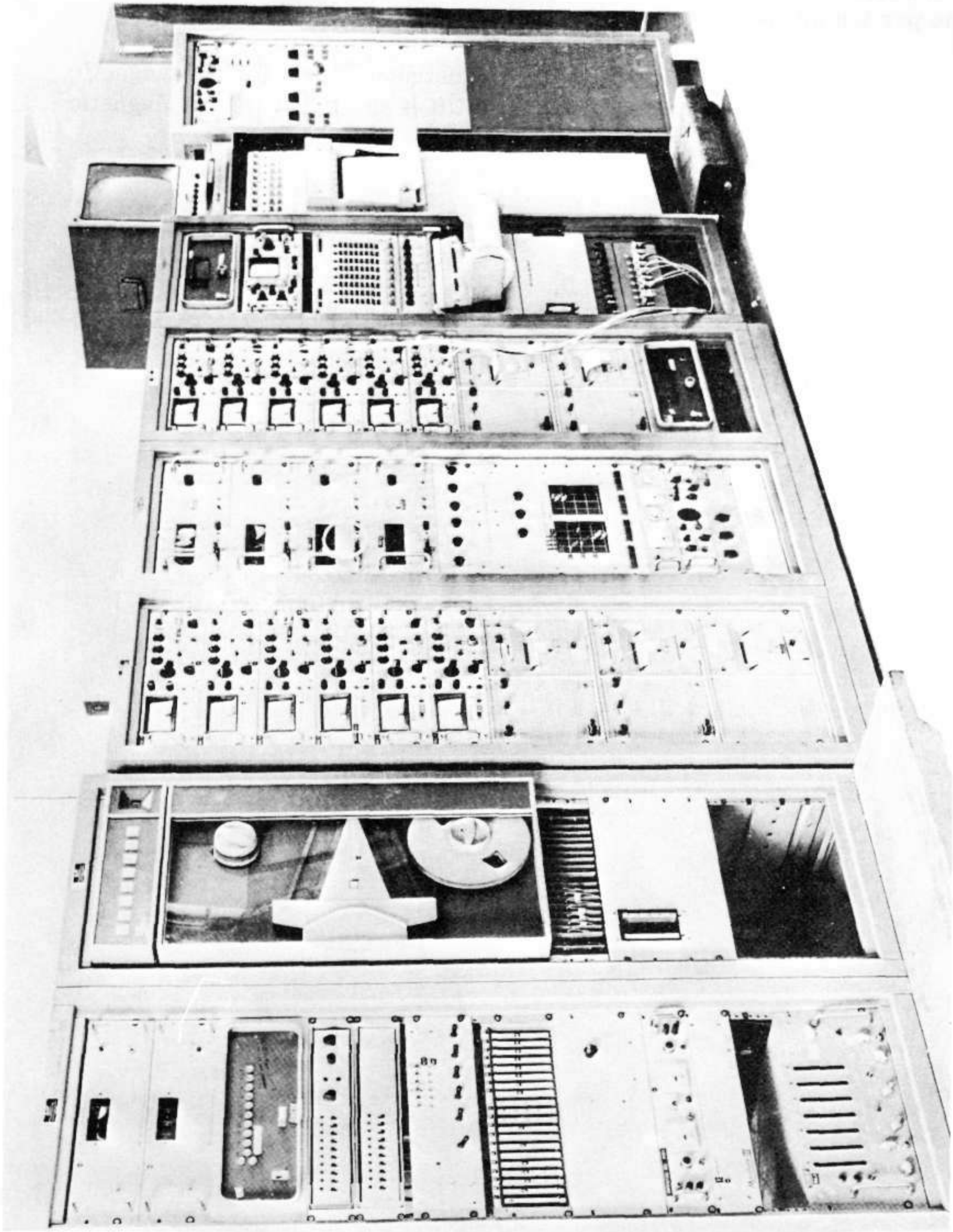


Figure A-2. Recording Instrumentation for Magnetic Tests

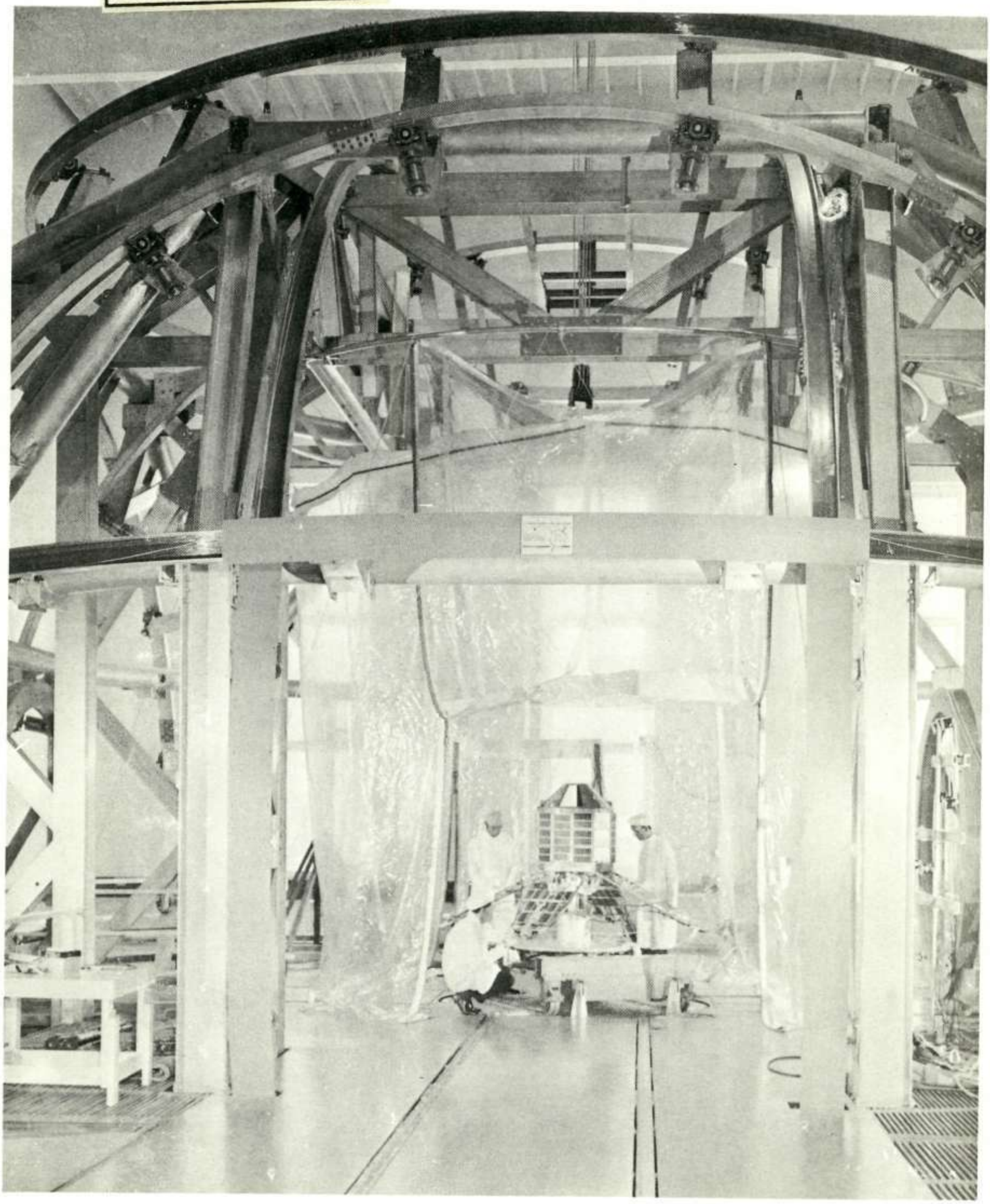


Figure A-3. UK-4 Spacecraft in the Spacecraft Magnetic Test Facility

APPENDIX B

TEST PROCEDURES

DIPOLE DETERMINATION

With the spacecraft in the truck lock, zero field is established at the center of the coil, using the station Schoenstedt magnetometer. All four Forster Hoover probes are then adjusted to read zero. The spacecraft is then rolled in on the dolly and rotated clockwise (as seen from above) through a complete revolution about a vertical axis.

The magnetic field data obtained from the procedure just described allows calculation of the dipole moment components on the assumption that near field effects can be disregarded and that the measured field is due to a theoretical dipole. The total moment in the XY plane may be calculated from the peak-to-peak Forster Hoover readings as follows:

$$M_{xy} = \frac{(H_x)\,p\text{-}p\ r^3}{4}$$

$$M_{xy} = \frac{(H_y)\,p\text{-}p\ r^3}{2}$$

The vertical component of dipole moment may be calculated by subtracting the Hz with spacecraft out of the coil from the average Hz obtained during rotation of the spacecraft in the center of the coil. The expression used is

$$M_z = \left[(H_z)\ \text{in}\ -\ (H_z)\ \text{out}\right] r^3$$

When significant distortion appears in the probe signatures during rotation, near field analysis will produce more accurate results. The mathematics of this approach, which are quite complex, will not be described here. Reference 3 contains a description of the process. The magnetometer data are recorded in digital form on magnetic tape (MADAS system), and calculations are performed by digital computer, using a GSFC program written for this purpose.

Vertical exposure consisted of dc-energizing of the pair of 2.7 meter (9 foot) diameter deperming coils within which the spacecraft was centered. The current was adjusted to produce a field level of 1.5 milliteslas (15 gauss).

Deperming was accomplished by slowly alternating the flux produced by the 2.7 meter (9 foot) diameter coils in the form of DC pulses. Current to the coils was programmed to produce pulses alternating in polarity with a period of approximately 12 seconds and gradually reducing from 2.5 millitesla (25 gauss) to zero amplitude in a period of 5 minutes.

TORQUEMETER TESTS

Calibration — The torquemeter was mechanically calibrated using a small precision weight which was applied at the outer radius of a bellcrank calibrator. This caused a torque of 1960 x 10^{-7} newton meters (1960 dyne-cm) to be applied to the torquemeter as a calibration signal. The torquemeter was also magnetically calibrated using the north-south and east-west torquemeter solenoids. When these solenoids were energized with a given current, they produced a known dipole moment. This moment, when interacted with an applied facility field, produced a known calibrating torque.

Permanent Dipole Moments — The X and Y components of the permanent dipole moment were measured with the spacecraft in the untilted position. A nulling technique was used, in which the X or Y component was countered by producing an equal and opposite dipole moment with the corresponding torquemeter solenoid. For example, to determine the X component of dipole moment, a field of 60,000 nanoteslas was oscillated at 1.9 radians per second in an east-west direction. This was the torsional resonance of the assembly, thus a dynamic augmentation of the signal resulted. The north-south (X axis) solenoid was energized and the current varied until the torque record showed a minimum. The X dipole moment component was then calculated as:

$$M_X = CI$$

where

M_X = X dipole moment component

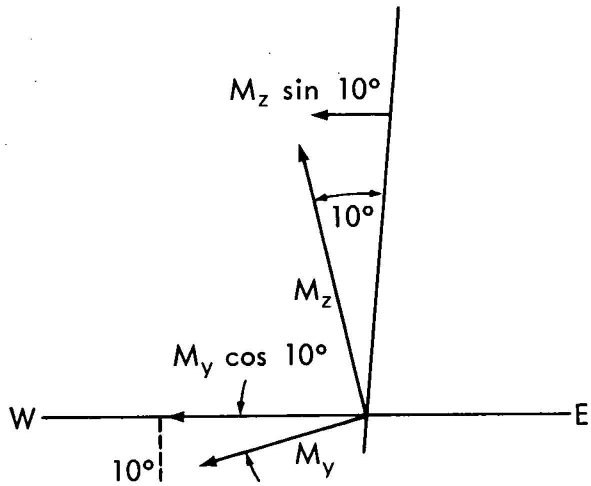
C = Solenoid coil constant

I = Solenoid current

The sense of the moment is opposite to that produced by the nulling current.

Determination of the Z component of permanent dipole moment required tilting of the spacecraft through a ten degree angle.

The hinge of the tilt plate was parallel to the X (north-south) axis as follows:



Tilting of the spacecraft reduces the horizontal component of M_y to $M_y \cos 10°$ and produces a horizontal component of $M_z = M_z \sin 10°$. The resultant east-west moment (M_{e-w}) is nulled out in the same way that the X and Y components were nulled before tilting the spacecraft. Assuming west positive, we have

$$M = M_y \cos 10° + M_z \sin 10°$$

so that

$$M_z \sin 10° = M - M_y \cos 10°$$

and finally

$$M_z = \frac{M - M_y \cos 10°}{\sin 10°}$$

Magnetorquer Coil Moments — The X and Y components of the coil moment were measured at zero tilt in the same manner as the permanent moment components; that is, by using the nulling technique. The coil moment components were obtained with the coil energized and with the coil off, with due regard to the algebraic sign.

The Z component of magnetorquer coil moment was measured with the spacecraft tilted ten degrees. A static field was applied in order to ensure that no dynamic effects were present on the coil. A north directed field was first applied, a zero obtained, then the magnetorquer coil was commanded on and the resulting static toruqe signal recorded. Taking into account the ten degree tilt, the Z component of magnetorquer coil was calculated from the expression:

$$M = (M_c)_y \cos 10° + (M_c)_z \sin 10°$$

where

$(M_c)_y$ = Y component of magnetorquer coil moment

$(M_c)_z$ = Z component of magnetorquer coil moment

finally we obtain:

$$(M_c)_z = \frac{M - (M_c)_y \cos 10°}{\sin 10°}$$

Eddy Current and Hysteresis Torque — In making these measurements, a field of 30,000 nanoteslas was rotated in the horizontal plane at a rate of 10.5 radians per second with the spacecraft shut down. No observable torque deflection occurred.

APPENDIX C

OPTIONAL FORM NO 10 5010-106
MAY 1962 EDITION
GSA GEN. REG. NO. 27

UNITED STATES GOVERNMENT

Memorandum

TO : C. L. Parsons
Head, Magnetic Test Section

DATE: November 3, 1971

FROM : C. A. Harris
Magnetic Test Section

SUBJECT: UK-4 Torquer Coil Measurements at WTR

On October 22, a trip was made to the WTR in order to investigate the difference between the moment levels of the prototype and flight spacecraft torquer coils. Based upon information obtained before departure, it was planned to perform a series of measurements on the coils under the following conditions:

a. Probe mounted on a stand and set up 12 feet from the spacecraft center aligned parallel to the Z axis.

b. Coils arranged in a manner which simulates GSFC measurement conditions.

c. Application of identical current levels to each set of coils.

d. Magnetometer heights adjusted to simulate plane of coil and spacecraft height measurement configurations.

e. Attempt to reconfigure the prototype torquer coil in order to decrease the effective coil area.

Late Friday evening after assembly of the prototype spacecraft had been completed, some preliminary measurements were made on the torquer coil. At this time it was found that by drawing the coil inward towards the spacecraft and thereby reducing the effective area, the moment of the coil decreased by as much as 15%. While bearing this in mind, the next morning's efforts centered on the preparation and measurement of the flight spacecraft torquer coil in order to obtain the desired comparison data. Once this had been accomplished, it was decided to attempt to reconfigure the prototype coil in the shape of the flight. The objective here was to find if the differences between the two coil moments had been caused by a difference in the effective areas of the two coils. Once this last set of measurements had been performed it became apparent that the moments of the two coils were close to becoming identical. This fact is illustrated by referring to the measurement results which are summarized in the following table:

SUBJECT: UK-4 Torquer Coil Measurements at WTR

TABLE I

UK-4 Torquer Coil Test Results

S/C	Battery Voltage (17.55 V = 300 ma)	Field At 12' (Gamma)	Coil Moment (Gauss-cm^3)	Temperature (^oF)	Remarks
Prototype	17.52	132	65,700	60	Normal Coil Configuration
	17.62	108	52,900		Coil Area Reduced
Prototype (Flt Coil Simulated)	17.47	90	44,100	72	Probe at Height of Coil
	17.47	75	36,680		Probe at Mid-Height of S/C
Flight	17.37	91.5	44,800	70	Coil Height
	17.38	78	38,200		S/C Height

The results tend to verify the fact that the previously reported smaller moment of the flight torquer coil had been caused by a reduction in the effective coil area. During the course of the measurements it was noted that the indicated moment values were lower than those observed at GSFC. Part of this problem was resolved after the instrument returned and was recalibrated. The only additional explanation for the remaining differences would be to take into account that these measurements were performed with a portable magnetometer while in an adverse environment.

During the course of the measurements the following courses of action were taken in order to eliminate any other variables:

SUBJECT: UK-4 Torquer Coil Measurements at WTR

a. Mylar tape similar to that used on coil checked and found to be nonmagnetic.

b. Probe raised and lowered to ensure that the plane of the coil height setting was valid.

c. Spacecraft aligned with +X axis directed towards magnetometer probe.

d. Current applied to coil and left on to check coil moment stability.

e. Second distance measurement check of field fall-off.

After having satisfactorily reviewed the results, the test was concluded.

C. A. Harris

C. A. Harris

APPENDIX D

CHRONOLOGY OF EVENTS

<u>Tuesday, 12 October 1971</u>

UK-4 spacecraft mounted on turntable at the Magnetic Test Site and solar paddle installed.

Measured initial perm moment "as received."

Performed vertical axis exposure.

Measured post vertical exposure magnetic moment.

Performed vertical axis deperm.

Measured post vertical deperm magnetic moment.

Extended Birmingham boom and measured magnetic moment.

Performed horizontal axis deperm.

Measured post horizontal deperm magnetic moment.

Performed horizontal axis rotational deperm.

Measured post horizontal rotational deperm dipole moment.

Installed compensation magnets.

Measured post compensation magnetic moment.

Measured induced dipole moment.

<u>Wednesday, 13 October 1971</u>

Measured stray field dipole moment.

Performed solar simulation.

Measured eddy current and hysteresis effects.

<u>Thursday, 14 October 1971</u>

Performed torque test of attitude control system.